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WATER RESOURCES TECHNICAL REPORT 1988

For Amoco CO_2 Projects Environmental Impact Statement

Prepared For:

U.S. Department of the Interior

Bureau of Land Management

Prepared By:

Planning Information Corporation

1801 Broadway, Suite 920

Denver, Colorado 80202

(303) 298-0919

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TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION 1
1.1 PURPOSE 1
1.2 OVERVIEW OF THE PROJECTS 1
1.3 SCOPE OF THE ENVIRONMENTAL IMPACT STATEMENT 1

CHAPTER TWO: AFFECTED ENVIRONMENT 3
2.1 INTRODUCTION 3
2.1.1 Climate 3
2.1.2 Drainages 4
2.1.3 Water Quality 6
Discharge. 6
Total Dissolved Solids (TDS) 7
Total Suspended Solids (TSS) 7
2.1.4 Stream Ratings 9
2.2 FONTENELLE CO_2 SUPPLY PROJECT 10
2.3 ELK BASIN CO_2 PROJECT 14
2.4 BEAVER CREEK CO_2 PROJECT 29
2.5 LITTLE BUFFALO BASIN CO_2 PROJECT 29
2.6 SALT CREEK CO_2 PROJECT 34

CHAPTER THREE: ENVIRONMENTAL CONSEQUENCES 38
3.1 INTRODUCTION 38
3.1.1 Significance Criteria 38
3.1.2 General Consequences 38
3.1.3 Potential Impact Avoidance 40
3.2 FONTENELLE CO_2 SUPPLY PROJECT 41
3.3 ELK BASIN CO_2 PROJECT 44
3.4 BEAVER CREEK CO_2 PROJECT 45
3.5 LITTLE BUFFALO BASIN CO_2 PROJECT 47
3.6 SALT CREEK CO_2 PROJECT 48

CHAPTER FOUR: REFERENCES 49

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LIST OF FIGURES

Figure 1-1. Location of Proposed Pipeline Alignments. 2

Figure 2-1. Major Drainages of Wyoming (Glass and Blacksone, 1987) 5

Figure 2-2. Proposed Fontenelle Project 11

Figure 2-3. Proposed Elk Basin Project 15

Figure 2-4. Proposed Beaver Creek Project 30

Figure 2-5. Proposed Little Buffalo Basin Project 33

Figure 2-6. Proposed Salt Creek Project 36

Figure 3-1. Plan and Profile of Typical Pipeline River Crossing 42

LIST OF TABLES

Table 2-1. Fontenelle CO_2 Supply Project--Perennial Streams Crossed . 12

Table 2-2. Fontenelle CO_2 Supply Project--Intermittent Streams Crossed 12

Table 2-3. Green River Water Quality Data 13

Table 2-4. Elk Basin CO_2 Project Perennial Streams Crossed 18

Table 2-5. Elk Basin CO_2 Project Intermittent and Ephemeral Streams Crossed 19

Table 2-6. Bitter Creek Near Garland, Wyoming, Water Quality Data . . 20

Table 2-7. Shoshone River Near Garland, Wyoming, Water Quality Data . 21

Table 2-8. Shoshone River Above Dry Creek Near Cody, Wyoming, Water Quality Data 22

Table 2-9. Whistle Creek Near Garland, Wyoming, Water Quality Data . . 24

Table 2-10. Dry Creek Near Greybull, Wyoming, Water Quality Data . . . 25

Table 2-11. Greybull River Near Basin, Wyoming, Water Quality Data . . 27

Table 2-12. Bighorn River at Worland, Wyoming, Water Quality Data . . . 28

Table 2-13. Beaver Creek CO_2 Project Perennial Streams Crossed. 31

Table 2-14. Beaver Creek CO_2 Project Intermittent and Ephemeral Streams Crossed 31

Table 2-15. Sweetwater River Near Sweetwater Station, Wyoming, Water Quality Data 32

Table 2-16. Little Buffalo Basin CO_2 Project Perennial Streams Crossed 35

Table 2-17. Little Buffalo Basin CO_2 Project Intermittent and Ephemeral Streams Crossed 35

Table 2-18. Salt Creek CO_2 Project Intermittent and Ephemeral Streams Crossed 35

Table 3-1. Quality Standards for Wyoming Surface Waters. 39

AMOCO CO_2 PROJECTS
WATER RESOURCES
TECHNICAL REPORT
CHAPTER ONE:
INTRODUCTION

1.1 PURPOSE

Amoco Production Company has proposed the development of five separate and distinct projects in the State of Wyoming. An Environmental Impact Statement (EIS) is being prepared to analyze the potential impacts associated with construction, operation, maintenance and abandonment of these five separate projects. This technical report was prepared to support the EIS analysis of potential impacts to water resources.

1.2 OVERVIEW OF THE PROJECTS

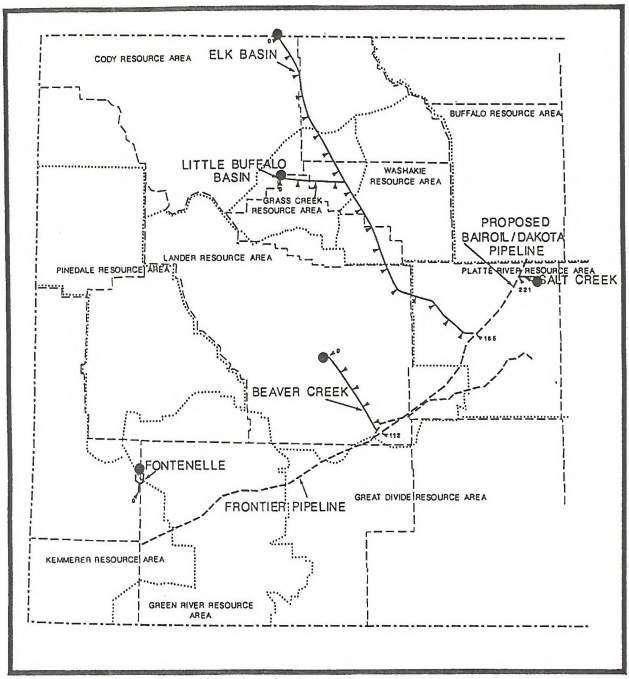
Amoco proposes to implement enhanced oil recovery, through the injection of CO_2, in four established fields: Elk Basin, Beaver Creek, Little Buffalo Basin and Salt Creek (Figure 1-1). The CO_2 would be supplied by the Fontenelle Project, which would obtain CO_2 from the nearby Raptor Field and process it for transport. Pipelines (16 or 18 inch) would be constructed to deliver the CO_2 in conjunction with existing CO_2 pipelines, to the four fields. A plant to recycle injected CO_2 would be constructed in each of the four fields.

The Fontenelle CO_2 Supply Project would be constructed in 1989 and 1990. Construction of the Elk Basin CO_2 Project would occur in 1989, 1990 and 1991. Construction of the Beaver Creek CO_2 Project is proposed for 1991, 1992 and 1993. The Little Buffalo Basin CO_2 Project is proposed for 1992, 1993 and 1994. The Salt Creek CO_2 Project's proposed construction is scheduled for 1993 through 1997.

Details of each project and schedules are included in Chapter 2 of the EIS.

1.3 SCOPE OF THE ENVIRONMENTAL IMPACT STATEMENT

The scope of the EIS is primarily restricted to analyzing the impacts associated with construction of CO_2 spur and trunk pipelines and the proposed gas processing and CO_2 recycle plants. While impacts of wellfield-related activities are discussed, precise plans and locations for wellfield-related activities are not available at this time. Analysis and mitigation of specific impacts associated with individual wellfield-related activities will be conducted after preparation of field development plans.



BLM RESOURCE AREA BOUNDARY
PROPOSED PIPELINE ALIGNMENT
EXISTING FRONTIER PIPELINE
PROPOSED BAIROIL/DAKOTA PIPELINE
COUNTY LINE
OIL OR CO_2 FIELDS
MILEPOST (10 MILES)

Figure 1—1. Location of Proposed Pipeline Alignments.

AMOCO CO_2 PROJECTS
WATER RESOURCES
TECHNICAL REPORT
CHAPTER TWO:
AFFECTED ENVIRONMENT

2.1 INTRODUCTION

The amount, temporal and spatial distribution and quality of Wyoming's water depends on several interactive factors. Of primary importance are climate, topography and land use. Secondary factors of importance are soils and vegetation because they modify climate and affect the amount of run-off versus infiltration and stored water. Low soil permeability and shallow soils with limited water holding capacity are significant limiting features of Wyoming soils.

Wyoming's mountain streams normally discharge their largest water volumes in late spring and early summer; volume and duration depend on winter snow accumulation and spring weather conditions. Intense summer thunderstorms can generate floodflows as well. In some cases, fall and winter streamflow is sustained by groundwater discharge. Irrigation demand and return flow can heavily influence time, volume and quality of flows. Some stream segments are completely dewatered by irrigation diversions.

2.1.1 Climate

In general, Wyoming has a relatively cool climate due to its elevation above sea level. The lower elevations in the Big Horn Basin and along the state's east-central and north-central borders are the warmest areas. Overall, July is the warmest month and January is the coldest.

Daily temperature fluctuations are influenced by cloud cover, changes in wind patterns and movements of air masses. During the summer months, daily ranges of between 35° and 45° F between the maximum and minimum temperatures are common. July mean maximum temperatures range between 85° and 90° F for most of the non-mountain stations in the state, with higher maximum temperatures recorded in the Bighorn Basin (Becker and Alyea, 1964a).

The winter months are characterized by rapid and frequent temperature changes. Canadian cold air masses generally move southeasterly and then easterly at this latitude; thus areas of the state east of the Bighorn Mountains and east of the Laramie Range are covered by the cold air masses for shorter periods of time. Some cold air masses are too shallow to move across mountain ranges like the Bighorns. However, when they do, cold air is trapped in the basin, creating longer periods of cold than usually occur in the adjacent areas.

Other localized temperature fluctuations are created by cold air "drainages" in valleys that trap cold air until strong winds can force it out, or by warm downslope "Chinook" winds that can significantly raise temperatures.

Seasonal precipitation patterns vary widely across the state. East of the continental divide, precipitation patterns are typical of the high plains (increasing precipitation during spring and early summer, a sharp drop in late June, leveling off or increasing in July and August, and decreasing to a minimum

in winter). Precipitation amounts may vary from as little as 1/2 inch per month in the winter to as much as 3 inches per month in the spring. Seasonal precipitation varies much less west of the continental divide, being more typical of that of the intermountain region. Across the state, annual precipitation varies widely from a minimum of 5 inches to a maximum of 45 inches.

The prevailing westerly winds, more predominant in the winter, cause much of the air's moisture to be precipitated over the mountain ranges from California to Wyoming. Thus, the western slopes of Wyoming receive more winter precipitation than does the eastern part of the state. In the spring and summer, the westerlies decline, and the region's circulation patterns are affected by moist air masses from the Gulf of Mexico. Upslope air flows from the Gulf result in lifting and cooling of the air, giving eastern Wyoming its late spring moisture. This same lifting and cooling is also caused by cold Canadian air masses and by convection from ground heating by the sun in warmer months. As the summer progresses, the air warms further and is able to hold more moisture, resulting in cumulus cloud formation and thundershowers across the state (Becker and Alyea, 1964b).

2.1.2 Drainages

The general drainage patterns of Wyoming are shown in Figure 2-1. Four major drainages occur in Wyoming: the Missouri River Basin, the Colorado River Basin, the Great Basin and the Columbia River Basin. The latter two basins are represented in Wyoming only along its western border, outside of the area of this project.

Three sub-basins of the Missouri River Basin occur in the project area. The Sweetwater River/North Platte River sub-basin occupies the central portion of the state, flowing to the east. The Powder River sub-basin and the Wind River/Big Horn River sub-basin lie to the north, and flow to the north. The Green River sub-basin lies within the Colorado River Basin in the southwestern corner of Wyoming, and flows to the south.

A division of waterways to perennial, intermittent or ephemeral is widely accepted, but the distinction between intermittent and ephemeral is not used consistently. The following definitions are used in this technical report and in the EIS. Note the distinction of relation to water table, and the size parameters that allow an otherwise ephemeral stream to qualify as an intermittent stream.

Ephemeral stream means a stream which flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice, and which has a channel bottom that is always above the water table.

Intermittent stream means 1) a stream or reach of a stream that drains a watershed of at least one square mile, or 2) a stream or reach of a stream that is below the local water table for at least some part of the year, and obtains its flow from both surface run-off and ground water discharge.

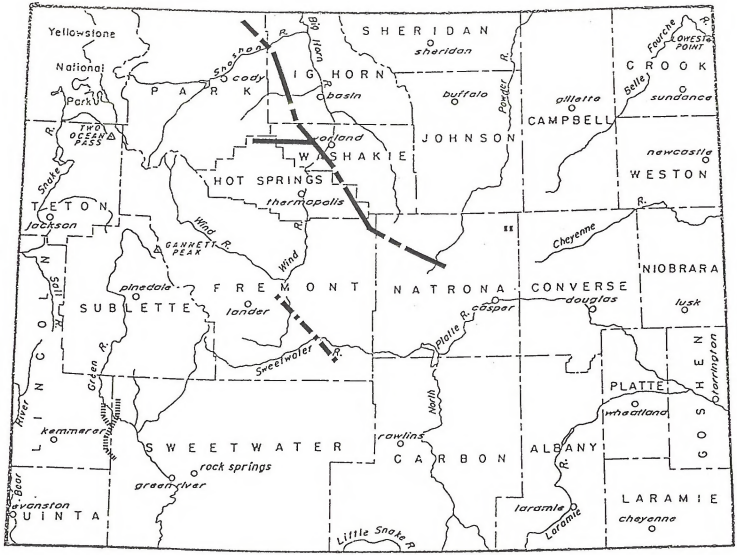


Figure 2—1. Major Drainages of Wyoming (Glass and Blackston, 1987).

Perennial stream means a stream or part of a stream that flows continuously during all of the calendar year as a result of ground water discharge or surface run-off. The term does not include intermittent stream or ephemeral stream (Federal Register, 1979).

2.1.3 Water Quality

Five measures of water quality were discussed in the analysis of project impacts: discharge, total dissolved solids, suspended solids, alkalinity and pH.

Discharge is the volume of water that passes a given point within a given period of time (U.S. Geological Survey, 1978-1987). Discharge supplies information on the amount of water being considered, information important to the assessment of scale and of dilution capacity. Discharge also indicates the energy of the flowing water, critical to an estimation of distances substances can be carried and of erosion potential.

The size of the particle able to be carried by moving water is proportional to a factor of velocity (Hynes, 1966). Basically, the faster water flows, the larger particle it can move. Run-off normally builds to a peak and then diminishes. As flows lessen, water-borne material begins to settle out, to be moved downstream at the next sufficiently high flow. A study on road construction and land development (Hansen et al., 1985) showed almost all of the sediment discharged occurred during high flows which occupied only 3 percent of the measured period.

The projects of interest here are not land development, which covers relatively large blocks of land. The issue of sediment movement mostly at highest flows is pertinent, however. A detailed study done in a forested/logged area (Rice et al., 1979) documented differing flow regimes in the matter of sediment transport. Stable watersheds and stream channels under "normal flows" are sufficiently stable to create an environment in which the stream has transporting power in excess of the available sediment. This regime is supply dependent. Periods or instances of high flow, however, can deliver a superabundance of transportable sediments. In this case, sediment discharge is not limited by the availability of sediment, but is, as noted above, a function of the velocity of the water. The sediment carrying capacity has become stream power dependent (Rice et al., 1979).

As discussed above, much of Wyoming's precipitation runs off as snowmelt or as the result of localized, often violent thunderstorms. Ephemeral and intermittent drainages, in particular, are likely to have readily available sediment for run-off event transport.

Sediment budgets are an attempt to quantify erosion effects. A sediment budget is a quantitative description of this movement of sediment through a single landscape unit (Swanson et al., 1982). While much scientifically viable work has been done, Rice (1982) has succinctly pointed out certain concerns. Working with chaparral systems, he found that the sedimentation regime was highly variable because of the interaction of marginally stable drainage basins, great variability in storm inputs and the random occurrence of brush fires. While fire is not as large an issue in the proposed project areas as it is in chaparral, certainly the situation of marginally stable drainage basins and great variability in storm input is pertinent. This author also notes the existence of approximately 4.5 "years" of record for use in building a

sedimentation model, but that it took 41 years to collect that 4.5 years of relevant data. Relatively few events in a year can be the overriding forces in developing sediment movement. Large and relatively infrequent run-off events are usually found to be responsible for most of the sediment transport during a stream's annual discharge cycle.

Total Dissolved Solids (TDS) are an aggregate of carbonates, bicarbonates, chlorides, sulfates, phosphates, and nitrates of calcium, magnesium, manganese, sodium, potassium and other cations that form salts. High TDS solutions can change the chemical nature of water, exerting varying degrees of osmotic pressures, and often become lethal to life in an aquatic environment (BLM, 1985a).

Total Suspended Solids (TSS) are defined as the concentration of all material suspended in a sample. Distinction between dissolved and suspended material is commonly by use of a "convenient operational definition" (U.S. Geological Survey, 1986). Dissolved material is defined as that which will pass through a 0.45 micron membrane filter and is often called total filtrable solids (TFS). Suspended material, by definition, is retained by a 0.45 micron membrane filter and may be referred to as total non-filtrable solids (TNS). Turbidity is a common measurement which can sometimes yield a rough approximation of TSS. However, turbidity should be clearly distinguished from a mass or concentration of suspended particles in a liquid. Turbidity is an expression of the optical property of a sample which causes light (generally white light) to be scattered and absorbed rather than transmitted in straight lines through the sample. Absorption and scattering of light is caused by dissolved, colloidal and suspended material. Turbidity is not directly relatable to TSS, but both parameters are usually positively correlated with each other. The Jackson Turbidity Unit (JTU), measured via a Jackson Turbidimeter, is the turbidity measure reported by the U.S. Geological Survey and is used in this report and in the EIS.

Alkalinity. Streams and rivers exhibit wide variations in relative acidity or alkalinity, not only in actual pH value, but also in the amount and type of dissolved material producing the acidity or alkalinity. Alkalinity is a term referring to the quantity and types of compounds which collectively cause a pH shift to the alkaline side of neutrality. In most natural waters, alkalinity is primarily due to the presence of bicarbonate, carbonate and hydroxide anions, and less frequently to borate, silicate and phosphate anions. Alkalinity is measured by titration of the sample with a strong acid to a specific pH end point necessary to neutralize the alkalinity anions. Data are usually expressed in terms of milligrams per liter as calcium carbonate (mg/l as $CaCO_3$).

pH. The pH parameter is an indicator of the intensity of acidity/alkalinity. A neutral solution has equal concentration of hydrogen protons (H+) and hydroxyl anions (OH^-), and a pH of 7.0. Acidic solutions have excess hydrogen protons and a pH of less than 7.0. Alkaline solutions have excess hydroxyl or alkalinity-producing anions and a pH greater than 7.0. The higher the pH, the greater the alkaline quality.

Natural waters are usually alkaline and possess buffering capacity. Buffering capacity is the ability to resist pH change. Alkaline salts of weak acids in solution will react with and neutralize hydrogen protons added from any strong acid source. Weak acid salts (e.g., $Ca(HCO_3)_2$, $CaCO_3$, etc.) are quite common in natural waters. They are derived from the reaction of CO_2 in solution with basic earth materials, and impart considerable buffering capacity to most natural waters. Buffering capacity in the pH range of 6.0 to 9.0 is important

because most biological reactions occur with maximum efficiency in this range. Most lethal effects on aquatic organisms due to excess acidity begin to occur near or below a pH of 4.5, while most lethal effects due to excessive alkalinity begin to occur near or above a pH of 9.5. Alkalinity and pH are generally monitored in water quality studies because of the potential detrimental effects of overwhelming a natural water's buffering capacity and allowing the aquatic habitat to become too acidic or too alkaline.

Aquatic systems are not subjected to wide swings in pH because of an inherent buffering system which tends to maintain the relative acidity/alkalinity "naturally occurring" or established in a stream. This buffering system is important to the proposed Amoco projects for two reasons: it greatly controls the range of pH and it involves carbon dioxide (CO_2), the product to be moved in the proposed pipelines.

The following is an abbreviated presentation; detailed explanations can be found in basic limnology texts (e.g., Hutchinson, 1957; Cole, 1966; and Wetzel, 1983):

Carbon dioxide is very soluble in water, approximately 200 times more soluble than the oxygen utilized by fishes and invertebrates. This dissolved CO_2 reacts slowly with the water to create carbonic acid:

a) $CO_2 + H_2O \text{ <----> } H_2CO_3$

Carbonic acid is a weak acid that dissociates more rapidly to free hydrogen ions and b) bicarbonate and c) carbonate:

b) $H_2CO_3 \text{ <----> } H^+ + HCO_3^{-1}$
c) $HCO_3^{-1} \text{ <----> } H^+ + CO_3^{-1}$

These reactions create free hydrogen ions (H^+) which, as noted above in the discussion of pH, make a solution more acidic.

The bicarbonate and carbonate ions, with water, also dissociate, forming d) carbonic acid and e) bicarbonate again, and also hydroxyl ions OH^{-1}:

d) $HCO_3^{-1} + H_2O \text{ <----> } H_2CO_3 + OH^{-1}$
e) $CO_3^{-2} + H_2O \text{ <----> } HCO_3^{-1} + OH^{-1}$

Water becomes more acidic by the addition of H+ ions. But, as shown above, the reactions go both directions until an equilibrium is reached. The additional H^+ ions combine with the OH^{-1} ions, but reaction e) allows carbonate to react with water to replenish the supply of OH^{-1} ions. This allows the H^+ and OH^{-1} equilibrium to become reestablished. The shifting back and forth of carbon dioxide/carbonic acid/bicarbonate/carbonate supplies the H+ ions to counteract added alkalinity, or supplies the OH^{-1} ions to counteract added acidity.

Carbon dioxide is always present in the atmosphere in a concentration of 0.03 to 0.04 percent. As such, there is, for practical purposes, an unlimited supply to streams and rivers. Waters with a pH below 5 have dissolved CO_2 as the dominant member of the buffering complex. Carbonates exist in a number of forms, with calcium carbonate most prevalent in fresh water. Carbonate is the dominant member of the buffering complex at a pH above 9. Bicarbonate dominates between pH readings of 7 and 9.

2.1.4 Stream Ratings

Chapter I of the Wyoming Department of Environmental Quality's Water Quality Regulations, entitled "Quality Standards for Wyoming Surface Waters," (WDEQ, 1983) designates all Wyoming waters as belonging to one of the following four classes:

> Class I: Those surface waters which shall be maintained at their existing quality and in which no further water quality degradation by point source discharges will be allowed.
>
> Class II: Those surface waters, other than those classified as Class I, which are determined by the Wyoming Game and Fish Department to be presently supporting game fish or have the hydrologic and natural water quality potential to support game fish.
>
> Class III: Those surface waters, other than those classified as Class I, which are determined by the Wyoming Game and Fish Department to be presently supporting non-game fish or have the hydrologic and natural water quality potential to support non-game fish.
>
> Class IV: Those surface waters, other than those classified as Class I, which are determined by the Wyoming Game and Fish Department not to have the hydrologic or natural water quality to support fish.

The Wyoming Game and Fish Department first developed a stream fishery classification map in 1961. The most recent update was in 1987 (Wyoming Game and Fish Department, 1987). The system emphasizes trout waters, not overall fisheries. Fisheries are discussed in the wildlife section of the EIS and in the Wildlife Technical Report. Because those sections rely on water quality information, the stream classification is included here.

The trout stream classification uses a number of characteristics to evaluate a stream's aesthetic value, availability and productivity. These values are weighted and combined to determine the stream's classification. Characteristics addressed for aesthetics are: stream channel characteristics (degree to which stream is degraded), water quality (turbidity and pollution), human development and landscape. Availability is rated based on land ownership (percent in public land or easements) and access to stream. The productivity rating is based on pounds of trout per mile. The final rating is calculated as:

> 4 x productivity rating + 2 x availability rating + 1 x aesthetic rating = final rating.

This value is then assigned to a stream class.

Five classes of stream are identified: 1) Premium trout waters--fisheries of national importance; 2) Very good trout waters--fisheries of statewide importance; 3) Important trout waters--fisheries of regional importance; 4) Low production trout waters--fisheries frequently of local importance, but generally incapable of sustaining substantial fishery pressure; and 5) Very low production waters--often incapable of sustaining a trout fishery.

2.2 FONTENELLE CO_2 SUPPLY PROJECT

The Fontenelle CO_2 Supply Project area (Figure 2-2) is in the Green River Basin, a portion of the Green River Drainage system. The proposed Fontenelle Gas Gathering System would be in the northeastern corner of the BLM's Kemmerer Resource Area and the northwestern corner of the BLM's Green River Resource Area. The region is composed of tablelands dissected by gullies, canyons and broad ancient stream valleys. Topographic relief ranges from 200 to 400 feet, and the area generally slopes to the east. Vegetative cover is dominated by sagebrush/grass and saltbush/winterfat (BLM, 1978).

The area's climate is semi-arid, with the average annual precipitation in the vicinity of the proposed project around 7 to 9 inches. Approximately 38 percent of the area's precipitation occurs from April through June. The large number of clear, sunny days (252/year) results in high evaporation rates (BLM, 1985b). The relative humidity is generally low, with highest levels in the winter months when snow cover remains in place. The average snowfall period runs from October to May (BLM, 1978), and the mean annual temperature is 38° F.

Soils in the area are typical of alluvial fans and high terraces, floodplains and low terraces and sedimentary uplands. Erosion potential is moderate to severe, with the highest erosion hazard on the residual uplands (BLM, 1978).

The BLM has characterized the water quality in the eastern two-thirds of the Kemmerer Resource Area as highly variable, due to the size and precipitation differences in the smaller sub-watersheds. Overall, however, the water type is classified as calcium bicarbonate. Salinity is the greatest limitation on water use and development in the resource area (BLM, 1985b), with high salinity concentrations resulting primarily from natural erosion. Flood plains adjacent to established drainages are especially susceptible to high salinity concentrations. Due to concerns over salinity, water quality plans must comply with the Colorado River Basin Salinity Control Act of 1974 (BLM, 1986b).

In 1986, the BLM established stipulations for surface disturbing activities within the Kemmerer Resource Area to reduce impacts to water quality and stream channels and to reduce sedimentation. Surface disturbance was prohibited:

- Within 500 feet of surface water and/or riparian areas, and
- During periods when the soil material is saturated, frozen or when watershed damage is likely to occur (BLM, 1986b).

A listing of the perennial streams crossed, with water quality and trout stream classification, is given on Table 2-1. Other streams are listed on Table 2-2. Data on discharge, dissolved solids, suspended solids, pH and alkalinity for the last ten years on the Green River are given on Table 2-3; no comparable data are available for Slate Creek.

<u>Green River Below Fontenelle Reservoir (Table 2-3)</u>. Mean discharges range from 690 to 2,778 cfs near the pipeline crossing for the period of record. Minimal flows (296 to 594 cfs) occur more frequently during fall and winter when run-off is stored in the upstream reservoir. Maximal flows (1,460 to 14,000 cfs) frequently occur in late spring or summer when the reservoir releases stored water.

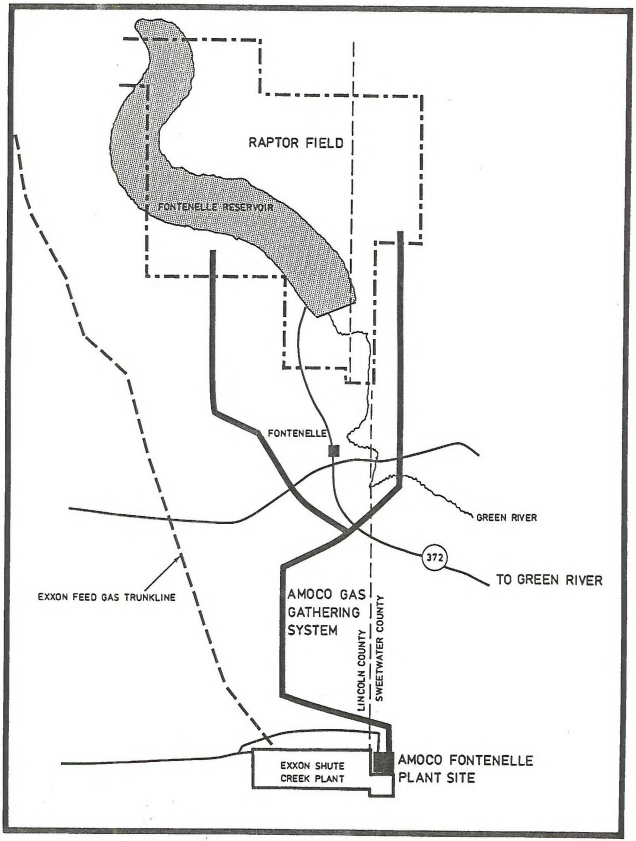


Figure 2—2. Proposed Fontenelle Project.

Table 2-1. Fontenelle CO2 Supply Project Perennial Streams Crossed.

Stream	Milepost Crossing (a)	Water Quality Classification (b)	Fishery Classification (c)	Water Quality Table #
Slate Creek	3W	II	5	
Green River	9	I	1	2 - 3

a = W indicates a position on the west branch of the gas gathering system.
b = Source: Wyoming Department of Environmental Quality, 1983.
c = Source: Wyoming Game and Fish Department, 1987.

Table 2-2. Fontenelle CO2 Supply Project Intermittent and Ephemeral Streams Crossed.

Stream	Number of Crossings	Milepost Crossing
Shute Creek	1	Plant Site
Unnamed tributaries to Shute Creek	9	1-5
Unnamed tributaries to Green River	4	7, 8W, 14E
Unnamed tributary to Slate Creek	1	10W
Total Number of Crossings	15	

a = W indicates a position on the west branch of the gas gathering stystem.

Table 2-3. Green River Water Quality Data.

Water Year	Flow (cfs) (Discharge)			TDS (mg/l)		Turbidity (JTU)		Alkalinity		pH		TSS (mg/l)	
	Mean	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1977	690	1,460	326	295	205	5	1	164	131	8.7	7.7	8	0
		Sep	Sep	Mar	Oct	Aug	*	*	Sep	*	Feb	*	*
1978	1,981	8,480	296	357	176	15	0	170	110	8.7	8.2	--	--
		Jun	Sep	May	Aug	Mar	Oct	Apr	Jun	Oct	*	--	--
1979	1,285	4,800	338	313	196	4	1	160	110	8.5	7.9	--	--
		Jun	Apr	Apr	Jun	*	*	Apr	Jun	*	Apr	--	--
1980	1,708	7,360	475	290	170	20	1	160	110	8.4	7.9	--	--
		Jun	Sep	May	*	Jul	*	*	Jul	*	Feb	--	--
1981	1,022	1,750	350	331	204	2	1	170	110	8.6	7.7	--	--
		Jun	Sep	Mar	Dec	*	*	Mar	*	Oct	Aug	--	--
1982	2,217	14,000	394	290	190	1	3	150	100	8.6	8.3	--	--
		Jul	Nov	*	Jul	Nov	Oct	Feb	Jul	Dec	Feb	--	--
1983	2,778	12,000	594	288	171	--	--	160	120	--	--	--	--
		Jul	Sep	Dec	Sep	--	--	*	*	--	--	--	--
1984	2,174	7,740	530	340	150	--	--	180	110	--	--	--	--
		Jul	Dec	Jan	Jul	--	--	Apr	Jul	--	--	--	--
1985	1,701	12,300	453	340	200	--	--	160	110	--	--	--	--
		May	Dec	Feb	May	--	--	Feb	May	--	--	--	--
1986	1,986	13,500	462	300	150	--	--	170	110	--	--	--	--
		Jun	Nov	*	Jul	--	--	Apr	Jul	--	--	--	--

* Maximum or minimum reading occurs more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

TDS concentrations are moderate (150 to 357 mg/l) and have few indications of being related to seasonal trends, as would be expected from water released from a major storage reservoir.

Turbidity values are low (< 5 JTU) in fall, and only low to moderate (1 to 20 JTU) during any season, as would be expected below a large reservoir.

Alkalinity values are moderate (100 to 180 mg/l as $CaCO_3$) at all times and exhibit a tendency to be higher in winter and spring than during greater run-off times in late spring and summer. No distinct relationship is evident between alkalinity and seasonal trends.

pH values are always moderately alkaline (7.7 to 8.7) and exhibit no distinct patterns nor seasonal trends, as is to be expected due to the effects of the upstream reservoir.

2.3 ELK BASIN CO_2 PROJECT

The proposed Elk Basin CO_2 Trunk Pipeline originates from the Bairoil-Dakota CO_2 Pipeline south of the town of Powder River. It would run west and northwest for approximately 178 miles to the Elk Basin Field north of the town of Powell, near the Montana border (Figure 2-3). The project area is drained by the Bighorn River and Powder River sub-basins, tributaries to the Missouri River Drainage System. The pipeline would follow existing pipeline rights-of-way through five BLM Resource Management Areas: Cody, Grass Creek, Washakie, Lander and Platte River.

The project area receives between 5 and 14 inches of annual precipitation. A detailed discussion of soil types is included in the Soils/Vegetation/ Agriculture Technical Report.

Within the Cody Resource Area, all of the proposed route is within the Bighorn River Drainage. The terminus of the pipeline in Elk Basin is on high ground, and areas just north and west are drained by Silver Tip Creek, which flows into Clark's Fork of the Yellowstone River.

In the Grass Creek Resource Area, the project is in the Bighorn River Drainage, which is a major tributary to the Yellowstone River. Fifteenmile Creek, which is considered perennial along some portions of its course and ephemeral along others, is the largest ephemeral drainage in the Grass Creek Resource Area. Suspended sediment loads from the drainage averaged 603,000 tons per year from 1952 to 1972 (BLM, 1982).

Annual average precipitation for the region is 8 to 10 inches per year, and average run-off is approximately 0.16 inch per acre per year. Soils in the project's vicinity formed in parent materials derived from shales, sandstones and igneous rocks, and are poorly developed. They are easily weathered, fine-textured, soft in consistency and poorly aggregated, with a high salt concentration. These soils are highly erodible; the BLM has determined that 75 percent of surveyed streams have accelerated stream bank erosion (BLM, 1982).

Sediment from erosion is considered to be the most serious water quality problem in the Grass Creek Resource Area (BLM, 1982). The WDEQ's 208 Water Quality Management Plan indicates Fifteenmile Creek is the major sediment-producing drainage in the Bighorn Basin and the No. 1 priority stream in need of erosion

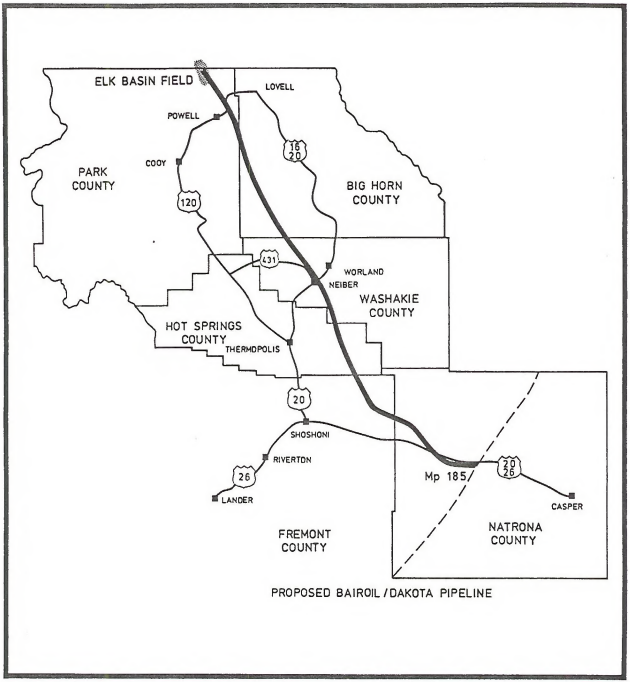


Figure 2—3. Proposed Elk Basin Project.

control measures. Based on the Bighorn Basin 208 Plan, the BLM is seeking to reduce soil erosion and sediment yields in the Fifteenmile Creek watershed (as well as the Kirby Creek and Nowater Creek watersheds) through applying Watershed Best Management Practices (BMPs), including livestock management and stabilization of the watershed with water flow and sediment control structures. The quality of produced water discharges is required, at a minimum, to meet the State's Chapter VII Water Quality Regulations. The BLM (1987) has further stipulated that:

> Future water discharges from mining activities, wastewater treatment facilities, etc., into drainages and surface waters would be regulated by the National Pollutant Discharge Elimination System (NPDES) permit process.

Overall, water quality of streams in the Grass Creek Resource Area is poor, due to bacterial contamination at lower elevations from livestock and wildlife grazing. Of the perennial stream miles surveyed by the BLM in the resource area, 75 percent are considered to be declining in stability and habitat values, and 50 percent of those that are stable are in poor condition (BLM, 1982).

The proposed pipeline would run north to south in the north-eastern portion of the Grass Creek Resource Area. Vegetative cover in this area includes sagebrush/grassland, barren badlands, saltbush shrub and some pockets of riparian and cropland.

The portion of the project area within the Washakie Resource Area is drained by the Kirby Creek Drainage, one of two main tributaries to the Bighorn River Drainage in the western portion of the Washakie Resource Area. The Kirby Creek Watershed is a highest priority area (designated by the BLM in 1986) for watershed project planning. Kirby Creek is considered perennial at its headwaters and intermittent from Blue Springs Creek to the confluence with the Bighorn River. Water quality in Kirby Creek is directly affected by oil field discharge water; there are high concentrations of TDS and high sodium sulfite levels at the headwaters. The Kirby Creek system drains 110,000 acres and carries an estimated annual sediment load of 40,000 tons (BLM, 1986c). Kirby Creek and Nowater Creek are mentioned in the 208 Water Quality Management Plan as sediment contributors.

The proposed pipeline would run through the Bighorn Mountains in the extreme northeastern corner of the Lander Resource Area, in the Gas Hills Management Unit. The Bighorn Mountains separate the Bighorn River Drainage to the northwest from the Powder River Drainage to the southeast.

Soils in this area are derived from Paleozoic rocks. Parent materials include ocher-colored siltstones, cherty dolomites (Dinwoody Formation) and phosphatic siltstone and shale (Phosphoria Formation).

Perennial streams in the Lander Resource Area are generally of good quality, although concentrations of TSS from soil erosion are considered the most serious water pollutant in the area (BLM, 1986a).

The proposed Elk Basin CO_2 Trunk Pipeline would originate at the Bairoil-Dakota pipeline in the northwestern corner of the Platte River Resource Area, in an area where three Resource Management Units (RMUs) intersect. These include the South Bighorns RMU, the Pine Mountain and Goldeneye RMU and RMU 14, which encompasses all lands in the resource area not included in the other RMUs. The project area would cross three designated sensitive drainages in the Powder

River Drainage: the Badwater and Alkali Creek Drainages, in the Bighorn River Drainage; and Wallace Creek Drainage. The proposed pipeline would be constructed in a designated corridor along the Lost Cabin-Arminto Road.

Soils in the area are those typical of the mountains and mountain valleys, generally dark and usually moist in some parts of the summer. These trend into soils of the eastern Wyoming plains: dark- and light-colored soils on upland plains, terraces and fans; formed from residual materials on steep uplands; usually moist in some places in the summer. Annual precipitation averages 14 to 24 inches in areas of mountain soils, and 12 to 16 inches in the plains. Precipitation along the pipeline corridor averages 12 inches annually. The soils are affected by salt and alkali and are subject to gully and wind erosion (BLM, 1984a).

The sensitive drainage designations of Badwater Creek, Wallace Creek and Alkali Creek warrant further study by the BLM of these watersheds to establish the need for protective measures or watershed management plans, such as seeding, grazing restrictions, water spreader construction, or water detention/retention facilities and intermediate and long-term monitoring on streams for pollutants (BLM, 1984a).

A listing of the perennial streams crossed, with water quality and trout stream classification, is given in Table 2-4. Other streams are listed in Table 2-5. Data on discharge, dissolved solids, suspended solids, pH and alkalinity for the last ten years are given in Tables 2-6 through 2-12.

Bitter Creek Drainage (Table 2-6). Mean daily discharge varies from 108 to 154 cubic feet per second (cfs) during the decade of records. Minimum flows occur in winter at about 10 to 17 cfs. Maximum flows (294 to 438 cfs) occur in late summer, probably in response to discrete precipitation events. Spring freshet is only rarely a time of high flow, perhaps due to relatively low accumulations of snow.

Maximal TDS values (947 to 1,410 mg/l) occur during the relatively low flow periods of winter. Minimal TDS values (356 to 501 mg/l) occur during the relatively high flow periods of late spring and summer when dissolved solids are more diluted by rainfall and snowmelt.

Turbidity is high (100 to 280 JTU) due to soil erosion during high discharges, and low (< 5 JTU) during low flows.

Alkalinity is moderate (130 to 180 mg/l as $CaCO_3$) during times of high discharge in late spring and summer, and is much higher (300 to 330 mg/l as $CaCO_3$) during lower winter flows. Dilution of dissolved salts by rainfall is probably responsible for the lower alkalinities in late spring or summer.

The pH is moderately alkaline (7.7 to 8.0) during late summer and may be slightly higher (7.8 to 9.2) during spring and fall. The highest pH values occur during the low flows of winter and early spring when TDS and alkaline salts concentrations are greatest.

Shoshone River Drainage (Tables 2-7 and 2-8). Minimal data are available for the pipeline crossing nearest the U.S. Geological Survey water quality station near Garland. Additional water quality data are available, however, from a U.S. Geological Survey station upstream of the pipeline crossing, above Dry Creek, near Cody. These data are discussed here.

Table 2-4. Elk Basin CO2 Project Perennial Streams Crossed.

Stream	Milepost Crossing	Water Quality Classification (a)	Fishery Classification (b)	Water Quality Table #
Bitter Creek	20	II	3	2-6
Shoshone River	21	II	3	2-7, 2-8
Whistle Creek	28	II	4	2-9
Dry Creek	40	II	4	2-10
Greybull River	44	II	4	2-11
Willow Creek	47	IV	5	
Middle Fork, Fifteenmile Creek	74	IV	5	
Bighorn River	87	II	4	2-12
Kirby Creek	117,119	II, IV(c)	4	
West Kirby Creek	111	II	4	
West Bridger Creek	121	II	4	
Bridger Creek	132	II	4	

a = Source: Wyoming Department of Environmental Quality, 1983.
b = Source: Wyoming Game and Fish Department, 1987.
c = Kirby Creek's water quality classification is II above the Kirby Creek Oil Field, and IV below.

Table 2-5. Elk Basin CO2 Project Intermittent and Ephemeral Streams Crossed.

Stream	Number of Crossings	Milepost Crossing
Unnamed tributaries to Cottonwood Creek	6	2-8
Unnamed tributary to Little Polecat Creek	1	10
Unnamed tributary to Bitter Creek	1	19
Unnamed tributaries to Shoshone River	2	21
Grass Creek	1	27
Unnamed tributaries to Whistle Creek	12	22-28
Coon Creek	10	31-37
Unnamed tributaries to Dry Creek	3	37-38
Unnamed tributary to St. Joe Canal	3	49-51
Unnamed tributary to Dorsey Creek	1	52
Dorsey Creek	1	55
South Fork Dorsey Creek	1	56
Unnamed tributary to South Fork Dorsey Creek	1	56
Unnamed tributaries to Elk Creek	6	57-59
Elk Creek	1	59
Unnamed tributary to Corral Creek	1	62
Reservoir Creek	1	66
Fifteenmile Creek	1	72
Unnamed tributaries to Fifteenmile Creek	8	69-80
Unnamed tributaries to Bighorn River	4	84-90
Unnamed tributaries in Wildcat Gulch	2	91
Unnamed tributaries to Nowater Creek	19	93-100
Unnamed tributaries to Kirby Creek	12	101-109
Kirby Creek	1	103
Ackler Fork (off Kirby Creek)	1	114
Unnamed tributaries to Bridger Creek	3	122-123
Bridger Creek	1	120
Cottonwood Creek	1	134
Unnamed tributaries to Badwater Creek	2	136
South Fork Sand Creek	1	144
Unnamed tributaries to Alkali Creek	13	145-150
Red Creek	1	152
Unnamed tributaries to Red Creek	2	151
Alkali Creek	1	158
Unnamed tributaries to Alkali Creek	8	153-158
Unnamed tributary in Waltman Draw	1	165
Unnamed tributaries in Keg Spring Draw	3	169
Unnamed tributaries in Hohnen Draw	5	170-173
South Fork Powder River	1	175
Unnamed tributaries in Wyatt Draw	2	176
Unnamed tributaries to South Fork Powder River	5	176-178
Total Number of Crossings	150	

Table 2-6. Bitter Creek Near Garland, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Discharge)			TDS (mg/l)		Turbidity (JTU)		Alkalinity		pH	
	Mean	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1977	108	294	15	1,340	501	280	1	308	180	--	--
		Jul	Jan	Apr	May	May	*	Feb	May	--	--
1978	134	393	13	1,340	451	100	4	330	160	8.4	8.0
		Sep	Feb	Apr	Jul	Jun	Nov	Feb	Sep	*	Aug
1979	129	363	17	1,160	478	--	--	310	160	8.7	8.0
		Aug	Jan	Dec	Jun	--	--	Apr	Jun	Apr	*
1980	133	376	13	1,170	438	--	--	310	160	9.2	7.6
		May	Feb	Apr	Jul	--	--	Dec	Jul	Apr	Dec
1981	127	351	17	1,410	372	--	--	300	130	8.9	7.7
		Aug	Apr	Feb	Jun	--	--	Dec	Jun	Dec	Aug
1982	141	383	14	947	356	--	--	320	130	8.2	7.8
		Aug	Mar	Feb	Jul	--	--	Feb	Jul	Apr	Jul
1983	138	357	14	1,320	425	--	--	314	163	7.9	7.8
		Aug	Feb	Mar	Jun	--	--	Mar	Jun	*	Oct
1984	137	401	9.6	--	--	--	--	--	--	8.4	7.8
		Aug	Dec	--	--	--	--	--	--	Mar	*
1985	137	409	10	--	--	--	--	--	--	8.4	8.0
		Jun	Feb	--	--	--	--	--	--	Nov	*
1986	154	438	10	--	--	--	--	--	--	8.4	7.7
		Sep	Dec	--	--	--	--	--	--	Apr	Aug

* Maximum or minimum reading occurs more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

Table 2-7. Shoshone River Near Garland, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Discharge)			TDS (mg/l)		Turbidity (JTU)		Alkalinity		pH	
	Mean	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1977	361	1,110	9.5	--	--	--	--	--	--	--	--
		Nov	May	--	--	--	--	--	--	--	--
1978	827	5,780	58	--	--	--	--	--	--	--	--
		Jul	Jun	--	--	--	--	--	--	--	--
1979	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
1980	561	953	69	--	--	--	--	--	--	--	--
		Apr	May	--	--	--	--	--	--	--	--
1981	--	--	--	--	--	--	--	--	--	--	--
1982	--	--	--	--	--	--	--	--	--	--	--
1983	--	--	--	--	--	--	--	--	--	--	--
1984	--	--	--	--	--	--	--	--	--	--	--
1985	--	--	--	--	--	--	--	--	--	--	--
1986	--	--	--	--	--	--	--	--	--	--	--

-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

Table 2-8. Shoshone River Above Dry Creek Near Cody, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Instantaneous) Mean	Max	Min	TDS (mg/l) Max	Min	Turbidity (JTU) Max	Min	Alkalinity Max	Min	pH Max	Min
1977	606	1,060	200	782	270	10	1	305	123	--	--
		May	Mar	Mar	May	*	*	Mar	Jul	--	--
1978	826	2,410	173	821	148	30	2	300	70	8.2	7.7
		Jul	*	Dec	Jul	Jun	*	*	Jul	Jun	Jul
1979	721	1,340	580	540	199	35	2	210	90	8.5	7.4
		Jul	*	Mar	Jun	Mar	Feb	*	Jun	Oct	Jan
1980	1,148	5,140	280	659	124	260	6	270	61	8.6	7.4
		Jun	Feb	Feb	Jun	Jun	*	Jan	Jun	Feb	May
1981	1,047	5,000	270	597	127	310	2	260	62	8.6	7.0
		Jun	Mar	Feb	Jun	May	Nov	Mar	Jun	Dec	Jun
1982	1,090	6,400	290	1,370	380	65	2	310	150	8.6	7.2
		Jul	Dec	Dec	Oct	Aug	Dec	Dec	Oct	Nov	May
1983	1,074	2,460	672	--	--	36	10	--	--	8.0	7.5
		Jul	Mar	--	--	Jun	Mar	--	--	*	*
1984	1,617	5,150	401	--	--	--	--	--	--	8.1	7.6
		Jun	Jan	--	--	--	--	--	--	Feb	Jul
1985	763	1,280	514	--	--	--	--	--	--	8.3	7.6
		Jul	Jan	--	--	--	--	--	--	Apr	Aug
1986	1,506	5,240	156	--	--	--	--	--	--	8.3	7.5
		Jul	Nov	--	--	--	--	--	--	*	Aug

* Maximum or minimum reading occurs more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

Mean discharge varies from 606 to 1,617 cfs during the decade of record. Maximal flows (1,060 to 6,400 cfs) at both U.S. Geological Survey stations occur in summer, while minimal flows (69 to 672 cfs), which are approximately ten times less than the maximal, occur in winter and spring. Flow timing and magnitude are influenced by operations of Buffalo Bill Reservoir, located upstream near Cody.

TDS are minimal (124 to 380 mg/l) during high flows in summer and fall, and higher (540 to 1,370 mg/l) when dissolved solids are less diluted by precipitation events in winter.

Turbidity is negligible (< 5.0 JTU) during low winter flows, and moderate to high (10 to 310 JTU) during higher flows associated with freshet run-off and summer storms.

Alkalinity is moderate (61 to 150 mg/l as $CaCO_3$) when dissolved salts are diluted by rainfall in summer and fall; alkalinity is considerably higher (210 to 310 mg/l as $CaCO_3$) during the minimal winter flows when less dilution of alkaline salts occurs from precipitation.

The pH is neutral to moderately alkaline (7.0 to 8.6) during all times of the year, with minimal values (7.0) in spring, and maximal values (8.6) during low flow periods in fall and winter.

Whistle Creek Drainage (Table 2-9). Mean discharges are 16 to 33 cfs during the decade of record. Flows are minimal (0.06 to 0.86 cfs) in winter and early spring, and are maximal (70 to 1,230 cfs) in late spring, summer and fall. Maximal discharges probably occur in direct response to rainfall events in the drainage, while minimal flows occur when subfreezing temperatures dominate and the only precipitation is frozen.

TDS are minimal (234 to 441 mg/l) during relatively high flows in late spring, summer and fall. Highest TDS (4,050 to 7,280 mg/l) are associated with the low flows of winter and early spring when the least dilution by falling and melting precipitation occurs.

Alkalinity is moderate (98 to 130 mg/l as $CaCO_3$) during summer flows, but four to five times higher (410 to 700 mg/l as $CaCO_3$) during the low winter flows.

pH is always slightly to moderately alkaline (7.2 to 8.6) with no noticeable pattern relatable to discharge or season.

Whistle Creek waters may be influenced by produced water from nearby oil and gas fields (U.S. Geological Survey, 1976-1986). The maximal TDS values may represent relatively high salinity and/or sulfates from produced waters.

Dry Creek Drainage (Table 2-10). Mean discharge is relatively low and constant (33 to 44 cfs) for the data of record. Minimal flows (5 to 25 cfs) occur in any time of the year. Maximal flows (63 to 492 cfs) are probably in direct response to rainfall events in late spring, summer and early fall.

TDS values are minimal (637 to 801 mg/l) in summer and early fall, and are maximal (830 to 2,880 mg/l) during low flow periods of winter and early spring when not diluted by falling or melting precipitation.

Table 2-9. Whistle Creek Near Garland, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Discharge) Mean	Max	Min	TDS (mg/l) Max	Min	Turbidity (JTU) Max	Min	Alkalinity Max	Min	pH Max	Min
1977	15.8	91	.10	7,280	374	--	--	700	130	--	--
		May	Jan	Feb	Jul	--	--	Feb	Jul	--	--
1978	32.9	1,230	.83	4,090	234	--	--	410	82	8.6	8.2
		May	Mar	Jan	Jul	--	--	*	Jul	Jun	Jul
1979	26.3	251	.45	5,290	441	--	--	560	98	8.6	7.7
		May	Jan	Jan	Oct	--	--	Jan	Jun	Oct	Jan
1980	26.1	477	.06	4,050	323	--	--	440	110	8.6	7.2
		Sep	Feb	Feb	Jul	--	--	Dec	Jul	Sep	Dec
1981	21.4	244	.86	4,120	255	--	--	400	100	8.5	7.5
		May	Mar	Mar	May	--	--	Dec	Jul	May	Nov
1982	27.0	493	.11	4,250	282	--	--	410	91	8.4	7.8
		Jun	Feb	Apr	Jul	--	--	Feb	Jul	Apr	Feb
1983	22.5	101	.66	4,480	403	--	--	452	126	8.1	7.8
		May	Dec	Jan	Jun	--	--	Jan	Jun	Mar	Oct
1984	19.4	70	.40	--	--	--	--	--	--	8.3	7.6
		Aug	Dec	--	--	--	--	--	--	*	May
1985	22.2	207	.15	--	--	--	--	--	--	8.5	7.9
		Jun	Feb	--	--	--	--	--	--	*	Oct
1986	20.3	123	.52	--	--	--	--	--	--	--	--
		Jun	Dec	--	--	--	--	--	--	--	--

* Maximum or minimum reading occurs more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

Table 2-10. Dry Creek Near Greybull, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Discharge)			TDS (mg/l)		Turbidity (JTU)		Alkalinity		pH	
	Mean	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1977	--	--	--	--	--	--	--	--	--	--	--
1978	33	121 Aug	8.7 Jun	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
1979	44	63 Jun	25 Sep	830 Sep	736 Jun	230 Jun	40 Sep	270 Sep	210 Jun	8.4 Jun	8.1 Sep
1980	34.5	492 Sep	4.6 Jan	2,880 Mar	637 Sep	-- --	-- --	300 Mar	220 Sep	8.7 Oct	7.9 *
1981	31	288 May	7.1 May	2,680 Feb	801 Sep	420 Feb	59 Nov	320 Nov	230 May	8.9 Sep	7.6 Nov
1982	--	--	--	--	--	--	--	--	--	--	--
1983	--	--	--	--	--	--	--	--	--	--	--
1984	--	--	--	--	--	--	--	--	--	--	--
1985	--	--	--	--	--	--	--	--	--	--	--
1986	--	--	--	--	--	--	--	--	--	--	--

* Maximum or minimum reading occures more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

Turbidity is minimal (40 to 59 JTU) during low flow periods in fall, and is maximal (230 to 420 JTU) in both summer (June 1979) and winter (February 1981). The only turbidity data of record are all moderate or very high values, indicating substantial erosion.

Alkalinity values are high (210 to 320 mg/l as $CaCO_3$) during all seasons sampled.

pH values always indicate a slightly to moderately alkaline (7.6 to 8.9) habitat during all seasons sampled.

Greybull River Drainage (Table 2-11). Mean discharge ranges from 63 to 239 cfs. Minimal flows (8 to 24 cfs) occur spring, summer or fall, and may occur at any time. Maximal flows (100 to 1,200 cfs) also occur during any season. No discernable pattern exists for flows with regard to season.

TDS values are usually minimal (180 to 620 mg/l) during summer, and are maximal (790 to 1,090 mg/l) during any season of the year. No seasonal pattern is identifiable for TDS values.

Alkalinity values range from 90 to 700 mg/l as $CaCO_3$. Minimal alkalinities are most often found in spring or summer. Maximal values are most frequently found in winter. No seasonal pattern is identifiable for alkalinity and flow, or alkalinity and TDS.

pH values are fairly uniformly alkaline (7.7 to 8.6), with no discernable seasonal pattern of variation.

Major water withdrawals and returns associated with nearby irrigation projects is likely responsible for the lack of seasonal patterns with the Greybull River water quality parameters.

Bighorn River Drainage (Table 2-12). Mean discharges range from 652 to 2,296 cfs for the decade of record. Minimal discharges (45 to 709 cfs) usually occur in late spring, summer or fall. Maximal discharges (1,200 to 6,830 cfs) usually occur in summer or winter, but have happened in all seasons. No seasonal pattern is obvious for flows.

TDS values are minimal (300 to 553 mg/l) in all seasons except spring, and maximal (638 to 1,000 mg/l) in any season. No seasonal pattern is obvious for TDS.

Alkalinity is minimal (110 to 160 mg/l as $CaCO_3$) during all seasons except spring, and is maximal (180 to 300 mg/l as $CaCO_3$) during any season. No seasonal pattern is obvious for alkalinity values.

pH values are fairly uniformly alkaline (7.6 to 8.7) and exhibit no seasonal nor flow-related pattern which is obvious.

The operation of the upstream Bighorn Reservoir and several major irrigation projects are likely responsible for the observed lack of seasonal patterns with the Bighorn River water quality parameters.

Table 2-11. Greybull River Near Basin, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Instantaneous) Mean	Max	Min	TDS (mg/l) Max	Min	Turbidity (JTU) Max	Min	Alkalinity Max	Min	pH Max	Min
1977	58.6	157	9.3	1,010	620	--	--	336	221	--	--
		Apr	Jun	Jun	Apr	--	--	Jan	May	--	--
1978	107.9	549	10	1,040	248	--	--	350	120	--	--
		Jul	Oct	Feb	Jul	--	--	Jan	Jul	--	--
1979	108	394	12	1,090	297	--	--	700	140	8.6	7.7
		Oct	Sep	Sep	Jun	--	--	Mar	Oct	May	Jun
1980	154.6	962	12	989	180	--	--	300	90	8.6	7.7
		Jul	Oct	Oct	Jul	--	--	Feb	Jul	*	May
1981	186.4	1,200	7.6	954	262	--	--	290	120	8.5	7.8
		May	Apr	Apr	May	--	--	*	May	Dec	Oct
1982	63.4	100	24	840	560	--	--	330	230	8.3	7.9
		Sep	Apr	Apr	Sep	--	--	Feb	Aug	Oct	Feb
1983	238.5	1,100	16	864	213	--	--	300	110	--	--
		Jun	Sep	May	Jun	--	--	Sep	Jun	--	--
1984	73.6	221	19	870	500	--	--	290	190	--	--
		Feb	May	May	Jun	--	--	May	Feb	--	--
1985	101.8	549	14	930	460	--	--	310	230	--	--
		Jun	Sep	Sep	Jun	--	--	Sep	Apr	--	--
1986	67.6	116	23	790	430	--	--	300	190	--	--
		Oct	May	Jan	Jun	--	--	Jan	Jun	--	--

* Maximum or minimum reading occurs more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

Table 2-12. Bighorn River at Worland, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Instantaneous) Mean	Max	Min	TDS (mg/l) Max	Min	Turbidity (JTU) Max	Min	Alkalinity Max	Min	pH Max	Min
1977	887	2,130	98	927	515	--	--	246	156	--	--
		Jan	Aug	Aug	Jan	--	--	Jun	Oct	--	--
1978	954	2,300	395	930	385	--	--	300	120	--	--
		Apr	Aug	Nov	Jul	--	--	Jan	Jul	--	--
1979	1,059	1,790	390	768	553	--	--	190	140	8.3	7.8
		Jun	May	Mar	Dec	--	--	*	Dec	Jun	Aug
1980	1,125	4,580	316	766	400	--	--	200	120	8.7	7.6
		Jul	May	Feb	Jul	--	--	*	Jul	Dec	Apr
1981	652	1,400	482	1,000	490	--	--	200	160	8.5	7.6
		Jun	Nov	May	Oct	--	--	Apr	*	Dec	Oct
1982	723	1,480	45	810	510	--	--	210	160	8.5	8.0
		Dec	May	May	Aug	--	--	May	*	Dec	*
1983	2,296	6,830	709	638	412	--	--	180	140	--	--
		Jul	Sep	May	Aug	--	--	May	Sep	--	--
1984	1,073	2,080	156	670	450	--	--	180	140	--	--
		Nov	Jul	May	Oct	--	--	*	Oct	--	--
1985	762	1,200	83	730	520	--	--	220	140	--	--
		Feb	May	Sep	Nov	--	--	*	Nov	--	--
1986	1,621	3,620	665	680	300	--	--	190	110	--	--
		Jul	Oct	Nov	Jul	--	--	Jan	Jul	--	--

* Maximum or minimum reading occurs more than once during water year.
-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

2.4 BEAVER CREEK CO_2 PROJECT

The Beaver Creek CO_2 Project area (Figure 2-4) is in the Wind River/Bighorn River Drainage, and the Sweetwater River/North Platte River Drainage. The area receives between 10 and 19 inches of annual precipitation. The watersheds are composed mainly of rangelands with relatively few perennial streams. Because run-off is mostly intermittent, there is a water deficit on most of the rangelands.

The proposed pipeline would enter the Wyoming Basin, generally west of the Granite Mountain Uplift and north of the Sweetwater Arch. The parent material for soils in this region is the White River Formation. Detailed information on soils is included in the Soils/Vegetation/Agriculture Technical Report. Erosion rates range from moderate to severe, the amount of impact being 1 to 2 tons per acre per year.

The project area is in the Beaver Creek Resource Management Unit (RMU) of the Lander Resource Area. Perennial streams in the Lander Resource Area are generally of good quality. The Sweetwater River is considered to be generally suitable for watering stock and wildlife. Area streams do, however, have the potential to carry very large amounts of TDS. Alkali Creek and West Alkali Creek, tributary to the Sweetwater River, carried TDS concentrations of 4,187 mg/l and 1,468 mg/l, respectively, in May, 1977 (BLM, 1986a). During years of excess precipitation and large run-offs, total annual loadings of TDS and TSS are highest. During low run-off and low flow periods, however, concentrations of TDS are highest.

Concentrations of TSS resulting from soil erosion are considered the most serious surface water pollutant in the Lander Resource Area. High erosion rates are common along the Sweetwater River.

A listing of the perennial streams crossed, with water quality and trout stream classification, is given on Table 2-13. Other streams are listed on Table 2-14.

Sweetwater River Drainage (Table 2-15). Discharge data are the only water data available from the U.S. Geological Survey station closest to the pipeline crossing. The next closest U.S. Geological Survey station with water quality data is located at Alcova, downstream of the two major reservoirs, Pathfinder and Alcova. Because of the influence from upstream reservoirs, water quality data at the Alcova Station displays few seasonally-related patterns applicable to this project.

Mean discharges at Sweetwater Station range from 46 to 241 cfs. Minimal discharges (6 to 29 cfs) occur during fall and winter, while maximal flows (441 to 3,340 cfs) occur during spring and early summer.

2.5 LITTLE BUFFALO BASIN CO_2 PROJECT

The Little Buffalo Basin CO_2 Project area (see Figure 2-5) is in the Bighorn River Drainage, which is a major tributary to the Yellowstone River. Average annual precipitation for the region is 8 to 10 inches per year, and average run-off is approximately 0.16 inch per acre per year. Soils in the project's vicinity formed in parent materials derived from shales, sandstones and igneous rocks, and are poorly developed. They are easily weathered, fine-textured, soft in consistency, poorly aggregated and with a high salt concentration. These

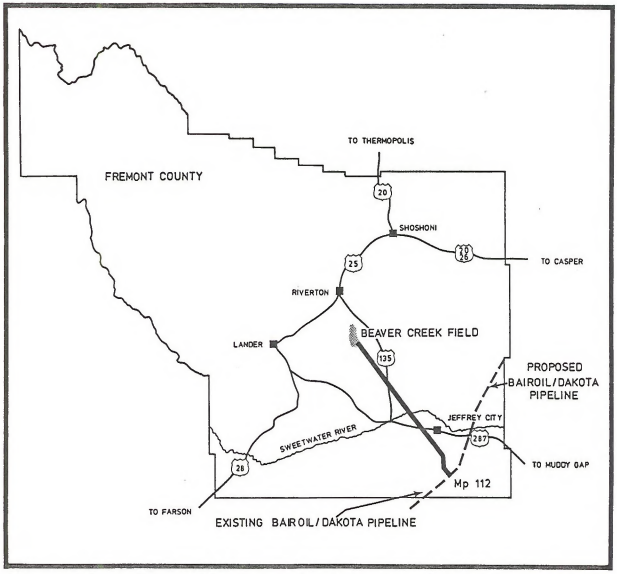


Figure 2–4. Proposed Beaver Creek Project.

Table 2-13. Beaver Creek CO2 Project Perennial Streams Crossed.

Stream	Milepost Crossing	Water Quality Classification (a)	Fishery Classification (b)	Water Quality Table #
Sweetwater River	25.0	II	3	2-15
Crooks Creek	40.0-42.5	II	3	

a = Source: Wyoming Department of Environmental Quality, 1983.
b = Source: Wyoming Game and Fish Department, 1987.

Table 2-14. Beaver Creek CO2 Project Intermittent and Ephemeral Streams Crossed.

Stream	Number of Crossings	Milepost Crossing
Unnamed tributaries to Beaver Creek	11	3.0-12.0
Unnamed tributary to West Fork, Long Creek	1	14.0
West Fork Long Creek	1	14.5
Unnamed tributaries to Cedar Rim Draw	2	16.0
Unnamed tributaries to Koehler Draw	2	19.5,20.7
Unnamed tributaries to Sweetwater River	11	22.0-26.0
Ice Slough	1	29.5
O'Brian Creek	1	35.0
Unnamed tributaries to Sweetwater River	4	33.5-37.0
Unnamed tributaries to Crooks Creek	11	38.0-44.0
Total Number of Crossings	45	

Table 2-15. Sweetwater River Near Sweetwater Station, Wyoming, Water Quality Data.

Water Year	Flow (cfs) (Instantaneous) Mean	Max	Min	TDS (mg/l) Max	Min	Turbidity (JTU) Max	Min	Alkalinity Max	Min	pH Max	Min
1977	46	852	5.6	--	--	--	--	--	--	--	--
		Apr	Jan	--	--	--	--	--	--	--	--
1978	134	902	7.6	--	--	--	--	--	--	--	--
		Jun	Jan	--	--	--	--	--	--	--	--
1979	122	878	8.5	--	--	--	--	--	--	--	--
		May	Nov	--	--	--	--	--	--	--	--
1980	238	2,880	21	--	--	--	--	--	--	--	--
		Apr	Sep	--	--	--	--	--	--	--	--
1981	78	441	10	--	--	--	--	--	--	--	--
		Jun	Sep	--	--	--	--	--	--	--	--
1982	149	839	9.6	--	--	--	--	--	--	--	--
		May	Feb	--	--	--	--	--	--	--	--
1983	241	3,340	23	--	--	--	--	--	--	--	--
		Apr	Dec	--	--	--	--	--	--	--	--
1984	154	1,550	29	--	--	--	--	--	--	--	--
		May	Jan	--	--	--	--	--	--	--	--
1985	87	646	9	--	--	--	--	--	--	--	--
		Apr	Feb	--	--	--	--	--	--	--	--
1986	232	1,760	14	--	--	--	--	--	--	--	--
		Jun	Dec	--	--	--	--	--	--	--	--

-- Data not available.
Source: U.S. Geological Survey. 1976-1986.

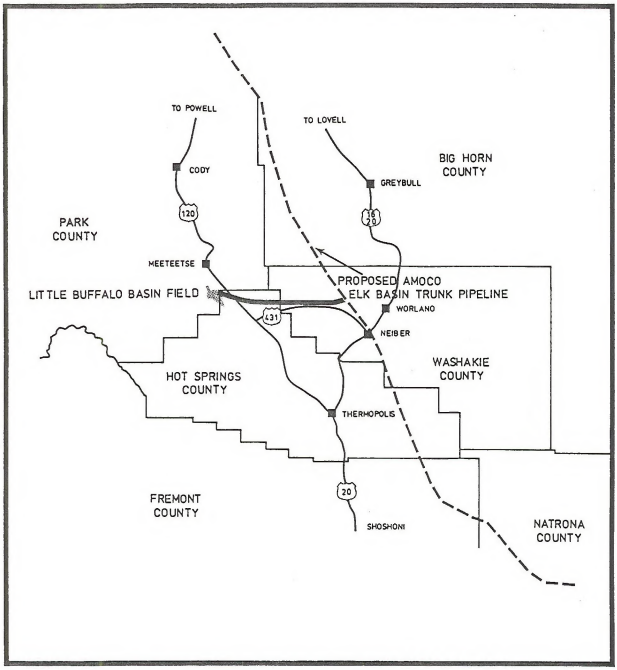


Figure 2—5. Proposed Little Buffalo Basin Project.

soils are highly erodible; the BLM has determined that 75 percent of surveyed streams have accelerated stream bank erosion (BLM, 1982).

The project area is in the central portion of the Grass Creek Resource Area, where sediment from erosion is considered to be the most serious water quality problem. Overall, water quality is poor due to bacterial contamination at lower elevations from livestock and wildlife grazing. Of the perennial stream miles surveyed by the BLM in the resource area, 75 percent are considered to be declining in stability and habitat values, and 50 percent of those that are stable are in poor condition (BLM, 1982).

The proposed pipeline would run east to west, adjacent to Gooseberry Creek and cross the creek in two places.

A listing of the perennial streams crossed, with water quality and trout stream classification, is given in Table 2-16. Other streams are listed in Table 2-17. U.S. Geological Survey data on discharge, dissolved solids, suspended solids, pH and alkalinity for the last ten years are not available for Buffalo Creek or Gooseberry Creek.

2.6 SALT CREEK CO_2 PROJECT

The Salt Creek CO_2 Project area (Figure 2-6) is drained by tributaries of the Missouri River System, and is in the Powder River sub-basin, which accounts for approximately 13 percent of the Missouri Basin Drainage. The area is characterized by shallow to deep soils that are well-drained, with gentle to steep slopes with rock outcrops. Deep drainageways cut through hard platy gray shale and soft underlying black shale; soils are affected by salt and alkali and are subject to gully and wind erosion (BLM, 1984a).

The project area is within the Platte River Resource Area. The project area includes the Salt Creek Area of Critical Environmental Concern (ACEC). The ACEC management plan has been implemented to reduce environmental impacts associated with oil production in the drainage (BLM, 1984a). The proposed pipeline would be in the Castle Creek Sensitive Watershed and adjacent to the Teapot Creek Sensitive Watershed.

Salt Creek has the highest concentration of salts and TDS in the Platte River Resource Area. Oil field discharge of brines from oil treatment facilities in the Teapot and Salt Creek oil fields contribute to this problem, as well as from natural sources. The water is not suitable for irrigation or livestock (BLM, 1984a). While Salt Creek has a relatively constant flow, TSS are high due to the surface disturbance in the oil fields (roads, well sites and treatment facilities), and the sparse vegetative cover.

The Salt Creek ACEC, encompassing the Salt Creek Drainage to its confluence with the South Fork of the Powder River, is covered by a BLM Management Plan. The BLM has implemented short-, intermediate- and long-term surveys (Level II) to monitor the cause and effects of erosion. BLM guidelines for surface water protection in the ACEC state that development impacting intermittent and ephemeral streams will be evaluated; if affected streams can potentially carry enough water to damage surface facilities or affected drainages have the potential to affect live streams,

- Site-specific mitigation will be applied if necessary; or

Table 2-16. Little Buffalo Basin CO2 Project Perennial Streams Crossed.

Stream	Milepost Crossing	Water Quality Classification (a)	Fishery Classification (b)
Buffalo Creek	7.5	IV	4
Gooseberry Creek	12.5, 14.9	II	4

a = Source: Wyoming Department of Environmental Quality, 1983.
b = Source: Wyoming Game and Fish Department, 1987.

Table 2-17. Little Buffalo CO2 Project Intermittent and Ephemeral Streams Crossed.

Stream	Number of Crossings	Milepost Crossing
Little Buffalo Creek	10	0.0-5.0
Unnamed tributaries to Little Buffalo Creek	6	5.7-10.8
Buffalo Creek	1	7.6
Unnamed tributaries to Gooseberry Creek	4	13.8-16.2
Unnamed tributary to Gooseberry Creek at Murphy Draw	1	18.8
Unnamed tributaries to Gooseberry Creek	8	19.4-33.3
Total Number of Crossings	30	

Table 2-18. Salt Creek CO2 Project Intermittent and Ephemeral Streams Crossed.

Stream	Number of Crossings	Milepost Crossing
Unnamed tributaries to Salt Creek	6	0.1-2.0
Unnamed tributaries west of Bothwell Draw	4	3.3-4.3
Dugout Creek	1	7.5
Unnamed tributaries to Dugout Creek	3	7.6-7.9
Government Creek	4	8.4-8.6
Total Number of Crossings	18	

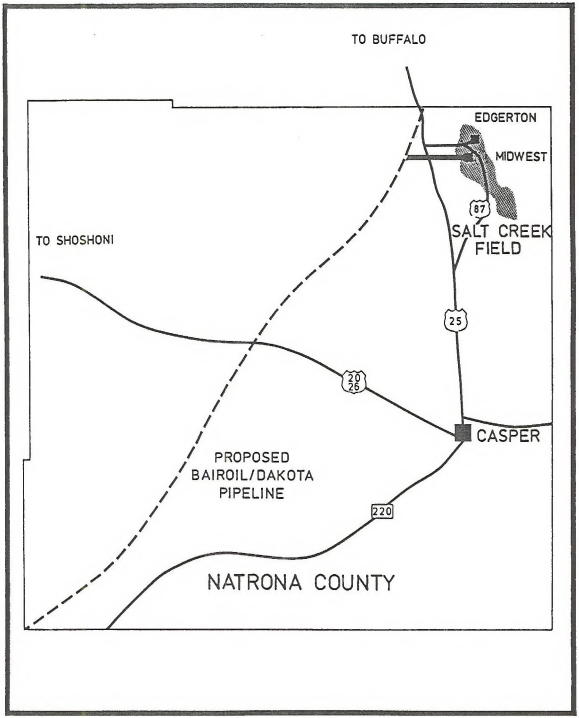


Figure 2—6. Proposed Salt Creek Project.

- Development will be moved a sufficient distance to ensure drainage integrity (BLM, 1985a).

The sensitive drainage designations of Castle Creek, Salt Creek and Teapot Creek require further BLM study to establish the need for protective measures or watershed management plans (seeding, grazing restrictions, water spreader construction or water detention/retention facilities), and intermediate- and long-term monitoring on streams for pollutants (BLM, 1984a).

The Salt Creek project pipeline does not cross any perennial streams. A listing of the non-perennial streams is given in Table 2-18.

3.1 INTRODUCTION

3.1.1 Significance Criteria

Water quality standards for surface water of the State of Wyoming are listed in Table 3-1. Additionally, "toxic or potentially toxic materials attributable to or influenced by activities of man shall not be present in any Wyoming surface waters in concentrations or combinations which would damage or impair the normal growth, function or reproduction of human, animal, plant or aquatic life. Unless otherwise specified in these standards, maximum allowable concentrations shall be based on the latest edition of Quality Criteria for Water, published by EPA or its successor agency, and/or more generally accepted scientific information" (WDEQ, 1983).

The Elk Basin Field, not including the site of the proposed CO_2 recycle plant or trunk pipeline, is drained by Silver Tip Creek into Montana. Applicable Montana surface water quality standards include:

- pH. No more than 0.5 change, natural pH above 7.0 must be maintained above 7.0.
- Turbidity. Less than 10 NTU increase.
- Temperature. Water above 55° F, maximum decrease of 2° F per hour. Water 32° F to 55° F, maximum decrease of 2° F.

3.1.2 General Consequences

Crossing of flowing waterways would temporarily increase the amount of sediment in the water column at the crossing site and for some distance downstream, depending on flow volumes and velocities. Streams can be supply dependent, a situation in which the stream has sufficient energy to move sediment but lacks available sediment, or stream power dependent, with sediment available but without sufficient energy to move that sediment (see Section 2.1). Creation of a trench across a stream supplies requirements for either stream type to move sediment: trenching digs up the sediment, and in doing so, lifts it into the water column.

Violations of water quality standards for pH and temperature would not likely occur with routine construction, operation, maintenance or abandonment. A temporary violation of water quality standards for turbidity increase may occur at the site of crossings and for a downstream distance of one to three miles (BLM, 1985c).

A non-routine operation would include the rupture of a CO_2 pipeline under a waterway. Because of the pressure (<2,000 psi) in the line, most of the CO_2 would be vented to the atmosphere. CO_2 is soluble in water, and would lower the

Table 3-1. Quality Standards for Wyoming Surface Waters.

Water Class	pH	Turbidity	Dissolved Oxygen	Temperature
I, II	6.5-9.0	No more than 10 NTU increase	1) Amount to allow no death or injury to existing aquatic life, and more than 6 mg/l. 2) No change over spawning areas.	1) No more than 2°F increase. 2) No change over spawning areas.
III	6.5-9.0	No more than 15 NTU increase	1) Amount to allow no death or injury to existing aquatic life, and more than 5 mg/l. 2) No change over spawning areas.	1) No more than 2°F increase. 2) No change over spawning areas.
IV	6.5-9.0	----	----	No more than 2°F increase.

pH. As discussed in Section 2.1, the natural stream buffering system is the carbon dioxide-bicarbonate-carbonate system. The potential to meaningfully reduce the pH is small.

Long-term sediment loads in streams would not likely increase more than 1 percent. Much of the projects' area and much of Wyoming in general has erodible substrate, resulting in a baseline that is seasonally very high in most streams. Snowmelt and summer thunderstorms, often violent and heavily localized, are largely responsible for this high baseline of sediment loading. Trenching across a stream creates a short-term impact. Reclamation procedures discussed below would reduce even short-term potential sediment loading from erosion attributable to the projects.

Characteristics of floodplains would not be changed such that flood flows would be impeded. Upon completion of construction, all pipeline rights-of-way would be re-contoured and reclaimed to BLM or landowner standards. None of the proposed plants is sited such that its presence would modify a floodplain to impede flood flows.

3.1.3 Potential Impact Avoidance

Most potential impacts would be avoided with the precautions built into the Plan of Development and BLM Standard Stipulations. Amoco would comply with the erosion control and reclamation programs outlined in this section and would comply with appropriate regulations, required plans and stipulations that would protect and restore any land disturbed by construction and operation to a stable, productive and aesthetically acceptable condition. Trees and shrubs that are not within the working area adjacent to the ditch would be protected from damage during construction.

Where the right-of-way crosses rivers, banks would be stabilized to prevent erosion. A buffer strip of vegetation above the higher water line would be left between the work staging area next to the river and the river itself. Care would be taken to avoid polluting all areas, including all rivers and their immediate drainage areas. Any spills would be cleaned up as required by the Authorized Officer or landowner. During construction near rivers and streams, straw bale filters would be built to prevent suspended sediments from reaching downstream watercourses as required by the Authorized Officer.

Areas would be backfilled in a manner to reduce further vegetation disturbance. The ground contour would be restored to permit normal surface drainage. In steep terrain, waterbars would be built to divert water from the pipeline trench and reduce soil erosion along the right-of-way and adjoining areas. All waterbars would extend at least five feet beyond the disturbed area and would be surveyed in by using at least a hand-held level.

Waterbars would be installed as needed to prevent erosion. General waterbar spacing would be as shown below:

Grade	Spacing (Feet)
5% and less	Normally none
5% to 15%	+_200
15% to 25%	+_100
25% or more	+_ 50

A certain degree of latitude is necessary in the waterbar interval spacing. Unstable soils may require a closer interval spacing whereas the interval spacing may be greater on very stable soils. Waterbars are to be constructed with a channel grade of approximately 2 percent. Waterbars are to be constructed beginning in vegetation (minimum of five feet) and feather out into vegetation (minimum of five feet) on the downhill side.

Where the pipeline right-of-way is parallel to the natural contour, or within 10 degrees of parallel, waterbars would not be installed unless serious erosion problems develop.

The proposed CO_2 spur and trunk pipeline alignments would cross the Shoshone, Greybull, Big Horn and Sweetwater rivers. The pipelines would be buried in a trench at these crossings. Amoco has aligned the pipelines to minimize impacts on riparian vegetation at all river crossings. All river crossings occur on existing corridors, minimizing the amount of disturbance expected to mature riparian areas (Vegetation Technical Report.)

Construction of all major river crossings would occur during low flow in the fall (typically September or October) but would be restricted to times which do not coincide with fall trout spawning. The pipeline trench would be built across the rivers at right angles wherever possible. Staging areas (200 feet x 400 feet) would be required on both river banks for equipment operation, welding and laydown. Streamflow would be maintained at all times during construction. The ditch would be dug by backhoe and/or dragline. Spoil from the excavation would be placed in locations as specified by U.S. Army Corps of Engineers Nationwide Section 404 Permit. The pipe would be buried deep enough so that high water would not affect the pipe through scour action but no less than 5 feet (top of pipe) below the riverbed (Figure 3-1). During backfilling, spoil would be distributed in such a manner that the riverbed would be similar to its original contour with no impediment to normal flow of water. River banks would be restored to resemble their original grade and rip rap would be placed over the pipeline on both banks, if necessary, to minimize erosion. Rip rap would be placed from ground level to the low water line. Amoco would consult with the Wyoming Game and Fish Department and the BLM to determine an appropriate seed mixture for reclaiming river banks.

The pipeline would be welded on one bank of the river before the trench is dug to reduce the time the river is open. Radiography would be used to inspect all field welds in submerged river crossings. The pipeline would then be placed into the trench and weighted with a 1-inch concrete jacket to ensure that it remains in the trench until covered.

Most crossings of intermittent and ephemeral streams would be conducted when no surface water is present. Such crossings would be completed within one day. Consistent with ANSI B31, block valves will be located at intervals of approximately 20 miles; these would help minimize the amount of CO_2 released in the unlikely event of a rupture.

3.2 FONTENELLE CO_2 SUPPLY PROJECT

The major river crossing for the Fontenelle CO_2 Supply Project is on the Green River below Fontenelle Dam. This stretch of river is a highly rated (Class I) fishery, as discussed in the Wildlife Technical Report. Fishery concerns on construction can be met by completing the crossing prior to October 1. The existence of the Seedskadee Wildlife Refuge downstream increases the overall

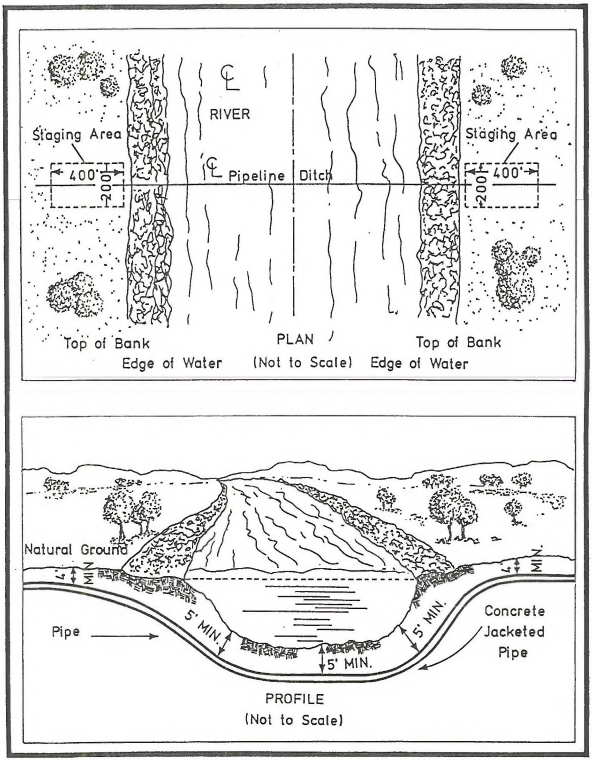


Figure 3—1. Plan and Profile of Typical Pipeline River Crossing.

sensitivity to disturbance. Coordination with the Bureau of Reclamation may allow for modification of flows to expedite the crossing (Morrison, 1987). Timing of crossing would minimize impacts to the fishery.

A potential impact unique to the Fontenelle CO_2 Supply Project is the introduction of hydrogen sulfide (H_2S) to a waterway in the unlikely event of a rupture. Gas from the Raptor Field contains H_2S (1.15 percent). (As a comparison, the Exxon LaBarge Field produces gas containing about 4 percent H_2S). The Raptor Unit is located on both sides of the Fontenelle Reservoir. The proposed Fontenelle Gas Processing Plant would be constructed on the west side of the Green River. The pipeline for that portion of the gas gathering system serving the east side of the Raptor Field must cross the Green River to reach the gas processing plant (Figure 2-2).

No phase of the proposed project--construction, operation, maintenance or abandonment--would intentionally introduce H_2S to the environment. The non-routine possibilities include a rupture or a slow leak in that portion of the pipeline under the Green River.

Details on the composition and workings of block valves are included in Chapter 2 of the EIS. Block valves are sited approximately 20 miles apart in these proposed projects. Because the pipeline carries even a small amount of H_2S, and because of the value of the Green River fishery, block valves will be located on both sides of the Green River crossing. Design parameters call for a closing of block valves within ten seconds of a rupture. This process, with the placement of valves on both sides of the river, minimizes the amount of gas that could escape into the Green River in the unlikely event of a pipeline rupture. The block valve on the eastern bank would stop the flow of gas from the Raptor Unit; simultaneously, the block valve on the western bank would prevent back flow of gas to the point of rupture.

The proposed crossing area contains other pipelines, including the AT&T Cable. The proposed route of this section of pipeline does not follow the shortest, most economical to build route, but swings more southward to cross the Green River (Figure 2-2). The justification for this longer route is to cross the Green River at this existing, established crossing, which has proven to be a safe, stable area.

In 1984, the BLM prepared an Environmental Assessment for the Cave Creek Sour Gas Gathering System. This system included a pipeline carrying gas with an H_2S concentration of 15 percent (greater than 10 times the concentration considered here) under the Bear River and a part of Woodruff Narrows Reservoir. This EA (BLM, 1984b) contained a thorough analysis of H_2S effects, and that information is utilized in the following discussion of potential impacts.

H_2S is toxic in its undissociated form, and dissolves readily in water. More dissociation occurs at a higher pH, and therefore a lower toxicity occurs. At a pH of 9.0, almost all of the H_2S is dissociated; at a pH of 7.0, approximately 50 percent is dissociated. The Green River has a measured pH range of 7.7 to 8.7 (Table 2-3). The maximum safe level (no effect) on fishes and aquatic invertebrates should not exceed 0.002 milligrams per liter at 20° C (BLM, 1984b).

A sudden rupture would throw sediment and water into the air. With the block valves quickly closing, much of the escaped gas would be vented into the air. Some mixing and dissolution of the H_2S into the water would occur. This area of H_2S contamination would be quickly diluted as it moved downstream, with rapid

oxidation of the H_2S to less toxic sulfides. Impacts to water quality would be temporary.

A slow leak would seep CO_2 and H_2S into the water column. A sufficiently slow leak would not cause closure of block valves, and could be difficult to detect. The gas bubbles may be dissolved before reaching the surface. The amount of H_2S entering the system would be very small, being only 1.15 percent of the gas stream. A leak would need to be very small to avoid having escaping gas bubbles reach the surface. This H_2S would be quickly diluted, and oxidation to less toxic forms would occur.

The acid gas waste stream from the Fontenelle CO_2 Supply Plant would be reinjected into the hydrocarbon-bearing Madison Formation. This would eliminate any potential impact to surface water resources.

3.3 ELK BASIN CO_2 PROJECT

The Elk Basin CO_2 Trunk Pipeline would cross three rivers: the Bighorn, Shoshone and Greybull. All are heavily drawn upon for irrigation between April and October (Vegetation Technical Report). No highly rated fisheries are present in these rivers or in the nine perennial streams at the points of crossing (Wildlife Technical Report). Impacts to spawning can be avoided by crossing important fishery streams prior to October 1.

Produced water is presently released from the Elk Basin Field under an NPDES Permit. At present, the discharged water seasonally contributes much of the flow of Silver Tip Creek in the vicinity of the Elk Basin Field. With CO_2 injection, most or all of this water would be returned to the reservoir. Silver Tip Creek drains the Elk Basin Field, flowing north into Montana. The area of the proposed recycle plant and pipeline is in the Bighorn River Drainage. The water quality of Silver Tip Creek would be improved with the proposed project, as the produced water presently being discharged under NPDES Permits contains a high degree of total dissolved solids. With the project, these dissolved solids would no longer be released into Silver Tip Creek.

Temporary increases in turbidity would occur with construction at all perennial streams and river crossings. These would temporarily (one day in most cases) violate the significance criterion in the vicinity of the crossing and for a short distance downstream. A temporary decrease in dissolved oxygen could occur in the immediate vicinity of the crossing if trenching cuts through reduced material. As this reduced material oxidizes, with stream water flowing over its surface or picking it up, the oxygen level in the stream could be reduced. This would be an impact occurring over a very short space and time. A violation of water quality standards, if occurring at all, would be very short-term and localized.

No effects on temperature and pH would be expected at waterway crossings. The turbidity plume, which could theoretically increase stream temperatures by raising the absorption of solar energy, is too short-term and diffuse. Variations in ambient conditions would overwhelm any differences that could be attributed to the plume. Effects to pH could occur if a strongly acidic or basic substratum is cut by the trenching. Such strata are not evident, and would have effect only for a short period of time, as stream crossing is accomplished generally within one day.

All of the crossings have been used in the construction of existing pipelines, indicating the crossings can be done without meaningful impacts.

Effects of introduction of CO_2 to a waterway from a rupture or leak in the pipeline are discussed in Sections 2.1 and 3.1.2 above. One variation of the discussed scenario is the occurrence of a leak or rupture under ice cover.

The Shoshone and Greybull Rivers are ice-covered at the proposed crossings, at least in most years. A rupture of the CO_2 pipeline would probably occur with such force as to crack the ice, allowing venting and giving the buffering system of the water access to the atmosphere. Closure of block valves would limit the amount of CO_2 released, regardless of ice cover. A slow leak could allow CO_2 to accumulate in the water under the ice. Effects of a leak small enough not to be detected would be diluted throughout the water body. Localized effects to pH could occur given the chain of events of a leak as large as is possible without triggering detection limits, as early in the season of ice cover as possible, and minimal movement of water in the river.

The Bighorn River in the area of the crossing does not normally experience ice cover, allowing venting and buffer system access to the atmosphere, as discussed in Sections 2.1 and 3.1.2.

Long-term sediment loads would not be expected to increase more than 1 percent in any of the waterways crossed. Sediment loading is detailed in Sections 2.1 and 3.1.2 above. A key aspect here is the highly erosional nature of most of Wyoming's watersheds. A significant impact under the above criterion could only occur with a massive long-term input of sediment from a crossing site. A moderate long-term input could violate significance criteria only if the input entered a waterway that was almost totally lacking in sediment load throughout the year. Additionally, and very importantly, the impact avoidance measures discussed in Section 3.1.3 would prevent or reduce further the potential for long-term sediment loading.

The third criterion states that a significant impact would occur if the characteristics of floodplains are changed so that flood flows would be impeded. The proposed site of the recycle plant would not be in a floodplain. Some support structures, such as block valves, could be sited in floodplains, but occupy so little space (~ 0.1 acre) that no impedance to flood flows would occur. The pipeline would be buried, with the trenched area recontoured to prevent status. The pipeline would be alongside pipelines that have been in place for several years, indicating its presence would not impede flood flows. No effects to flood flows would be expected with this proposed project.

3.4 BEAVER CREEK CO_2 PROJECT

The Beaver Creek CO_2 Trunk Pipeline crosses two perennial streams, the Sweetwater River and Crooks Creek. Both are given Fishery Classification III by the Wyoming Game and Fish Department (see the Wildlife Technical Report). Impacts to spawning would be avoided by crossing the streams prior to October 1.

Produced water is currently being released from the Beaver Creek Field under NPDES Permits. This water is not a major contributor to Beaver Creek. With CO_2 injection, most or all of the presently discharged water would be returned to the reservoir. This elimination of presently discharged water would improve the water quality of Beaver Creek, as the discharged water carries a high load of total dissolved solids.

Temporary increases in turbidity would occur with construction at all perennial streams and river crossings. These would temporarily (one day in most cases) violate the significance criterion in the vicinity of the crossing and for a short distance downstream. A temporary decrease in dissolved oxygen could occur in the immediate vicinity of the crossing if trenching cuts through reduced material. As this reduced material oxidizes, with stream water flowing over its surface or picking it up, the oxygen level in the stream could be reduced. This would be an impact occurring over a very short space and time. A violation of water quality standards, if occurring at all, would be very short-term and localized.

No effects on temperature and pH would be expected at waterway crossings. The turbidity plume, which could theoretically increase stream temperatures by raising the absorption of solar energy, is too short-term and diffuse. Variations in ambient conditions would overwhelm any differences that could be attributed to the plume. Effects to pH could occur if a strongly acidic or basic substratum is cut by the trenching. Such strata are not evident, and would have effect only for a short period of time, as stream crossing is accomplished generally within one day.

All of the crossings have been used in the construction of existing pipelines, indicating the crossings can be done without meaningful impacts.

Effects of introduction of CO_2 to a waterway from a rupture or leak in the pipeline are discussed in Sections 2.1 and 3.1.2 above. One variation of the discussed scenario is the occurrence of a leak or rupture under ice cover.

The Sweetwater River is ice-covered in the area of the proposed crossing in most years. Any pipeline rupture under the river would probably release a force of sufficient energy to crack the ice, allowing venting. This would also give the buffering system of the river access to the atmosphere. Closure of block valves would limit the amount of CO_2 released, regardless of ice cover. A slow leak, one below detection levels, could allow CO_2 to accumulate in the water under the ice. Effects of a leak small enough to preclude detection would be diluted throughout the water body. Localized effects to pH could occur given the chain of events of a leak as large as is possible without triggering detection thresholds, the leak starting at the very beginning of ice cover, and minimal movement of water in the river. Any effects would be lessened by areas of open water, and would be eliminated with the removal of the ice cover.

Long-term sediment loads would not be expected to increase more than 1 percent in any of the waterways crossed. Sediment loading is detailed in Sections 2.1 and 3.1.2 above. A key aspect here is the highly erosional nature of most of Wyoming's watersheds. A significant impact under the above criterion could only occur with a massive long-term input of sediment from a crossing site. A moderate long-term input could violate significance criteria only if the input entered a waterway that was almost totally lacking in sediment load throughout the year. Additionally, and very importantly, the impact avoidance measures discussed in Section 3.1.3 would prevent or reduce further the potential for long-term sediment loading.

The third criterion states that a significant impact would occur if the characteristics of floodplains are changed so that flood flows would be impeded. The proposed site of the recycle plant would not be in a floodplain. Some support structures, as block valves, could be sited in floodplains, but occupy so little space (~ 0.1 acre) that no impedance to flood flows would occur. The

pipeline would be buried, with the trenched area recontoured to prevent status. The pipeline would be alongside pipelines that have been in place for several years, indicating its presence would not impede flood flows. No effects to flood flows would be expected with this proposed project.

3.5 LITTLE BUFFALO BASIN CO_2 PROJECT

The Little Buffalo Basin CO_2 Spur Pipeline would cross two perennial streams, Buffalo Creek and Gooseberry Creek. Both are Class IV trout fisheries. Gooseberry Creek is heavily affected by irrigation uses.

Produced water has been, and is currently being released from the Little Buffalo Basin Field under NPDES Permits. The CO_2 injection will not significantly affect the discharge.

Temporary increases in turbidity would occur with construction at all perennial streams and river crossings. These would temporarily (one day in most cases) violate the significance criterion in the vicinity of the crossing and for a short distance downstream. A temporary decrease in dissolved oxygen could occur in the immediate vicinity of the crossing if trenching cuts through reduced material. As this reduced material oxidizes, with stream water flowing over its surface or picking it up, the oxygen level in the stream could be reduced. This would be an impact occurring over a very short space and time. A violation of water quality standards, if occurring at all, would be very short-term and localized.

No effects on temperature and pH would be expected at waterway crossings. The turbidity plume, which could theoretically increase stream temperatures by raising the absorption of solar energy, is too short-term and diffuse. Variations in ambient conditions would overwhelm any differences that could be attributed to the plume. Effects to pH could occur if a strongly acidic or basic substratum is cut by the trenching. Such strata are not evident, and would have effect only for a short period of time, as stream crossing is accomplished generally within one day.

All of the crossings have been used in the construction of existing pipelines, indicating the crossings can be done without meaningful impacts.

Effects of introduction of CO_2 to a waterway from a rupture or leak in the pipeline are discussed in Sections 2.1 and 3.1.2 above. One variation of the discussed scenario is the occurrence of a leak or rupture under ice cover.

Both streams are ice-covered in most years. A rupture would likely occur with sufficient force to break the ice and allow the escape of CO_2. Closure of block valves would limit the amount of CO_2 released. Effects of a leak small enough to preclude detection would be diluted through the water body, if the liquid portion is contiguous. Effects would be reduced by any cracks in the ice, and would be eliminated with the disappearance of the ice cover.

Long-term sediment loads would not be expected to increase more than 1 percent in any of the waterways crossed. Sediment loading is detailed in Sections 2.1 and 3.1.2 above. A key aspect here is the highly erosional nature of most of Wyoming's watersheds. A significant impact under the above criterion could only occur with a massive long-term input of sediment from a crossing site. A moderate long-term input could violate significance criteria only if the input entered a waterway that was almost totally lacking in sediment load throughout

the year. Additionally, and very importantly, the impact avoidance measures discussed in Section 3.1.3 would prevent or reduce further the potential for long-term sediment loading.

The third criterion states that a significant impact would occur if the characteristics of floodplains are changed so that flood flows would be impeded. The proposed site of the recycle plant would not be in a floodplain. Some support structures, as block valves, could be sited in floodplains, but occupy so little space (- 0.1 acre) that no impedance to flood flows would occur. The pipeline would be buried, with the trenched area recontoured to prevent status. The pipeline would be alongside pipelines that have been in place for several years, indicating its presence would not impede flood flows. No effects to flood flows would be expected with this proposed project.

3.6 SALT CREEK CO_2 PROJECT

The Salt Creek CO_2 Spur Pipeline does not cross any perennial streams. No impacts to water resources would be expected from the construction or operation of the project.

The Salt Creek CO_2 Project would be built within the Salt Creek Area of Critical Environmental Concern (ACEC). The proposed project would not have a significant effect on the ACEC goal to enhance water quality. Erosion controls discussed in Section 3.1.3 would be implemented at the plant site.

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